Space Weather Technical Forecast

Issued on Monday, 01 January 2024 at 01:18 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of M-flares, slight chance of X-flares. Slight chance G1-Minor storms from coronal hole fast wind onset day 1 (1st Jan).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: High with a single X5 flare from AR3536 at 31/2155 UTC. There are four numbered sunspots and a small newly emerged spot in the northwest. The most notable region is newly numbered AR3536, potentially returning ex-AR3514. This is a moderately sized region, but appears to have mixed polarities within very close penumbra regions in a north/south alignment. The spot remains simplified away from having a likely delta, but this may be reinstated as it moves into a less oblique viewing angle. Further spots or regions are also likely from over the east limb, based upon looping visible in SDO imagery. The other regions remain smaller, simpler and either stable or decaying.

There were several CME's observed through the period, with a number being analysed as likely missing Earth. This included a couple of filament eruptions off the northwest and southeast. However, a filament eruption CME off the northwest, at 31/1030UTC, and another filament eruption from he southeast around 31/1730 UTC may give glancing impacts at Earth day 3 (03 Jan). A further weak CME off the south of the disc was identified as likely coming from a subtle corona reconfiguration around 31/0300 UTC. While relatively slow, faint, and mainly southward directed, a glancing impact cannot be ruled out and analysis is still ongoing. Finally, the X5 flare is expected to have given a large CME from the northeast limb, though there has been a distinct lack of imagery since just before this event occurred, therefore an assessment at this time is not yet possible.

Solar Wind / Geomagnetic Activity: Background wind speeds were observed with a flat trend, averaging around 310 km/s. Density was generally around or below average. Interplanetary Magnetic Field (IMF), Bt, was generally weak between 0-8nT. The north-south component, Bz, was weak, fluctuating between +5/-5nT. Phi angle was negative (towards the Sun). Geomagnetic activity remained Quiet (Kp 0-1).

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was mostly at background, though a minor response post X5 flare was observed. GOES16 high energy (greater than 2MeV) electron flux ranged was mainly at background. The 24-hour fluence was below Active throughout. The 01/0000 UTC observation was 4.18e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low to Moderate activity is expected, with a chance of isolated M-flares due to the potential for a returning cluster of sunspots in the east that likely includes ex-AR3514.

Solar Wind / Geomagnetic Activity: There are several weak, potentially glancing CMEs that may have a very minor influence later in the period. Slow wind conditions initially, with background speeds, are expected to become elevated on day 1 (01 Jan) due to the onset of fast winds from CH86/-. Elevated winds are likely to persist day 2 before easing day 3 (02-03 Jan). CME influences may bring further spells of elevated solar winds at Earth, though this remains low confidence.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Met Office Space Weather Technical Forecast

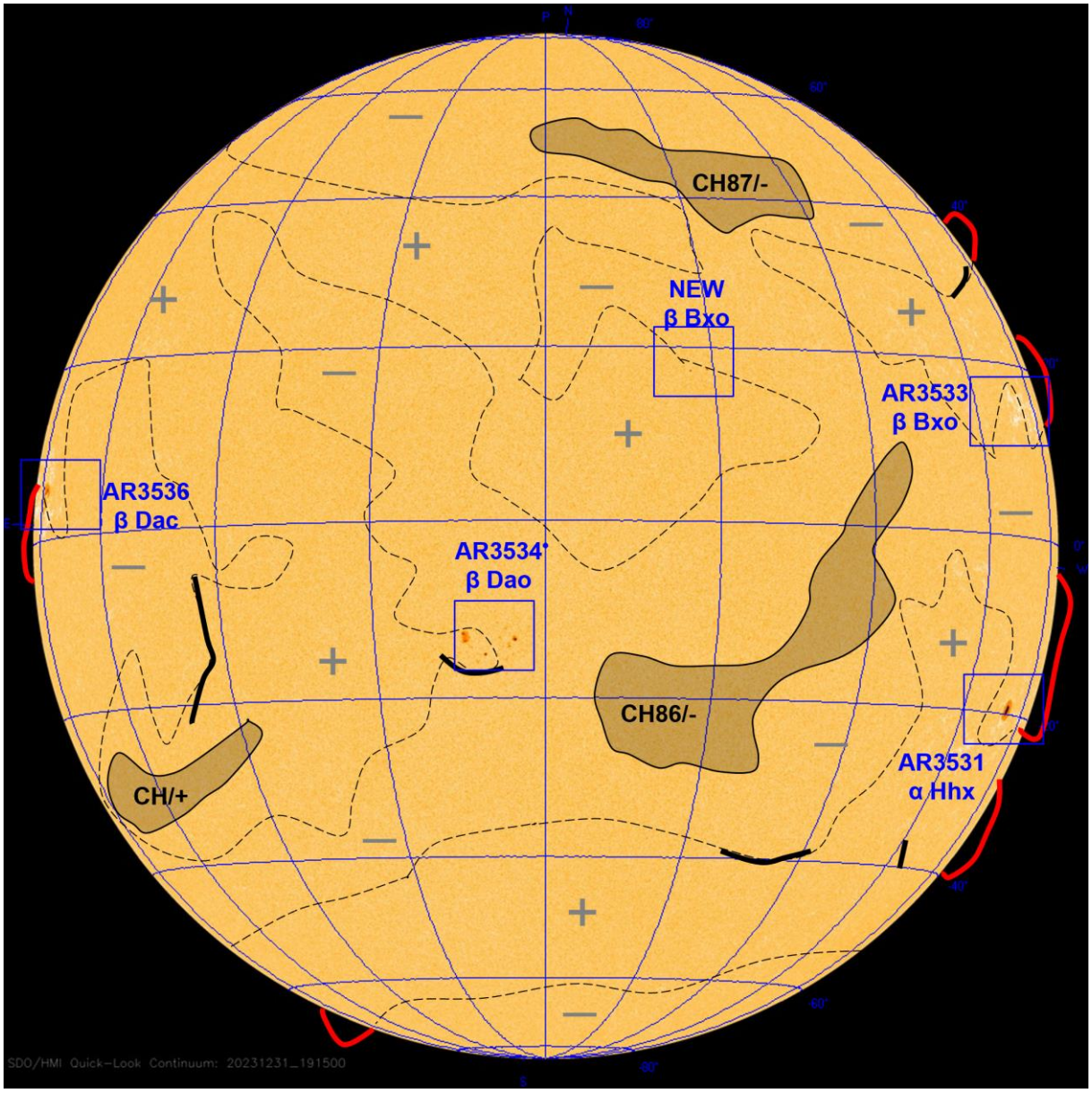
Quiet geomagnetic activity is expected to start, becoming Unsettled with a chance of Active intervals and a slight chance of G1 Minor storms on day 1 (01 Jan), before easing to Quiet with Unsettled intervals day 2 (02 Jan). However, Active intervals remain possible days 2-4 (02-04 Jan) from any very slight CME enhancement/s that may occur.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is expected to remain below S1 storm levels, though a moderate response from the X5 flare is ongoing at the moment. GOES16 high energy electron flux is likely to remain at background, but is expected to reach Moderate levels, with a chance of reaching High at diurnal peaks, from day 3 (03 Jan). The associated 24 hour fluence is expected to remain below Active through the period, but with a rising trend by the end of the period.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Figure 1. Solar Analysis Valid 31/2000 UTC



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Geomagnetic Storms:

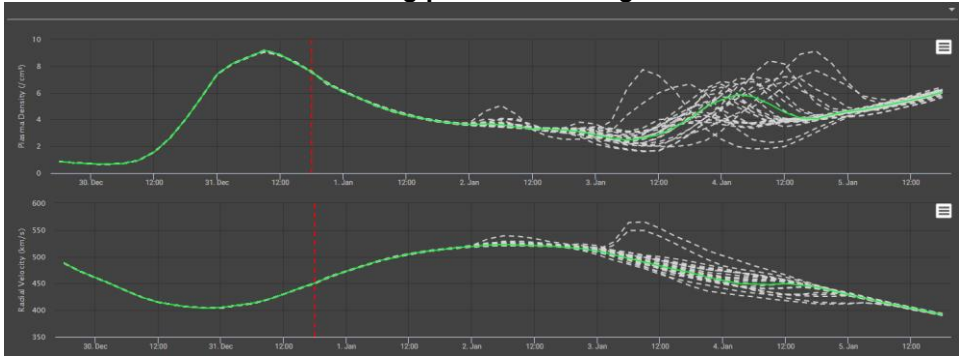
There are couple of weak, potentially glancing CMEs that may have a very minor influence later in the period. The first is a filament eruption off the southeast disc on 30 Dec. This is expected to miss but does have a very slight chance of glancing Earth early on day 3 (02 Jan). The second is from a C2.6 flare from AR3534 which followed the filament. This is low confidence, due to being faint and slow, but may give a very slight glance late on day 4 or early day 5 (03-04 Jan). A further CME was also observed on 31 Dec from the southwest disc, due to a corona reconfiguration. This was faint and relatively slow, and generally heading southward, however analysis is still ongoing for any Earth-directed impact. Another CME from a filament eruption in the southeast on 31st Dec has also been analysed and although likely missing, may give glancing impacts on 03 Jan. Finally, the X5 flare is expected to have given a large CME from the northeast limb, though there has been a distinct lack of imagery since just before this event occurred, therefore an assessment at this time is not yet possible.

Slow wind conditions initially, with background speeds, are expected to become elevated on day 1 (01 Jan) due to the onset of fast winds from CH86/-, in-line with MOSWOC Enlil. This is a relatively narrow feature compared with the last rotation, at least along its equatorial section, when solar wind speeds of 500-600km/s were observed and geomagnetic activity peaked at Unsettled. Similar speeds are expected on this occasion, however, as a persistent feature there is the chance for Active intervals and slight chance of G1/Minor Storms. Elevated winds are likely to persist day 2 before easing day 3 (02-03 Jan).

Overall mainly Quiet geomagnetic activity is expected to start, becoming Unsettled with a chance of Active intervals and a slight chance of G1 Minor storms on day 1 (01 Jan), before easing to Quiet with Unsettled intervals day 2 (02 Jan). However, Active intervals remain possible days 2-4 (02-04 Jan) from any very slight CME enhancement/s that may occur.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	20	5	20	10
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Figure 2: MOSWOC ENLIL Ensemble showing possible lancing CME effects later in the week.



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Radio Blackouts - X-Ray Flares:

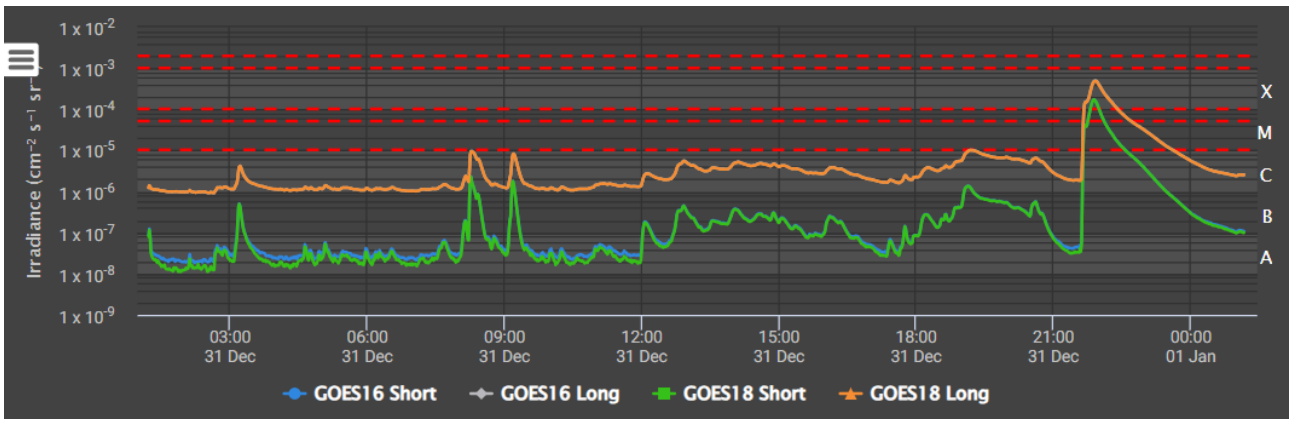
Solar activity has recently risen to High due to the X5 flare from AR3536 on the northeastern limb on New Years Eve. Low to Moderate activity is expected to dominate, with potential for the regions rotating around the eastern limb to give further M-flares and a slight chance of further X-flares.

There are four numbered sunspots and a small newly emerged spot in the northwest. The most notable region is newly numbered AR3536, potentially returning ex-AR3514. This is a moderately sized region, but appears to have mixed polarities within very close penumbra regions in a north/south alignment. The spot remains simplified away from having a likely delta, but this may be reinstated as it moves into a less oblique viewing angle. Further spots or regions are also likely from over the east limb, based upon looping visible in SDO imagery. The other regions remain smaller, simpler and either stable or decaying.

Far-side seismic products support the continued arrival of a notable active region or regions in the next 24 hours, which would correspond to the return a cluster of sunspots that included ex-AR3514, the source of the last X-flare on 14 Dec. The most recent Mars Perseverance rover image of the Sun, while from just over a week ago (22 Dec), shows this cluster of spots persisting on the far-side. Due to this, the risk of flares is maintained through the period.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	50	50	50	50
Very Active	R3 to R5 X Class	No	10	10	10	10

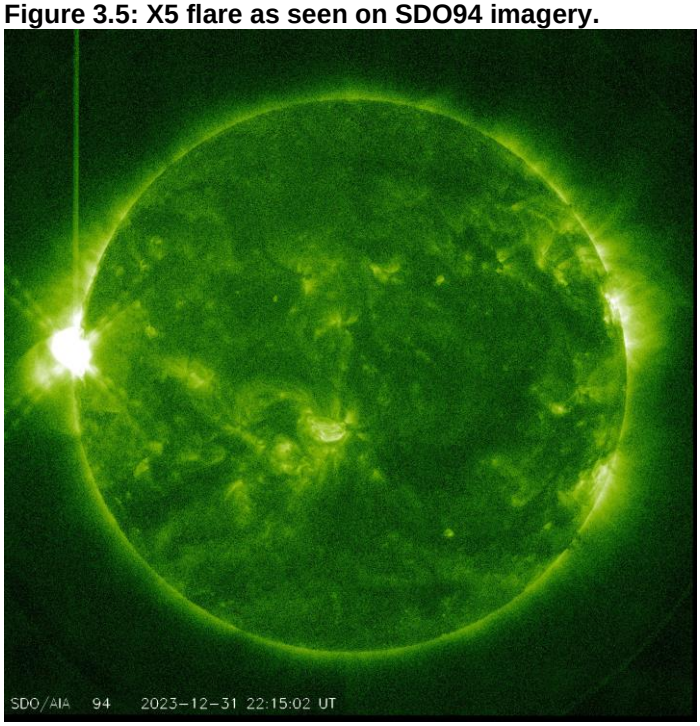
Figure 3: 24 hour X-ray trace



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Figure 3.5: X5 flare as seen on SDO94 imagery.



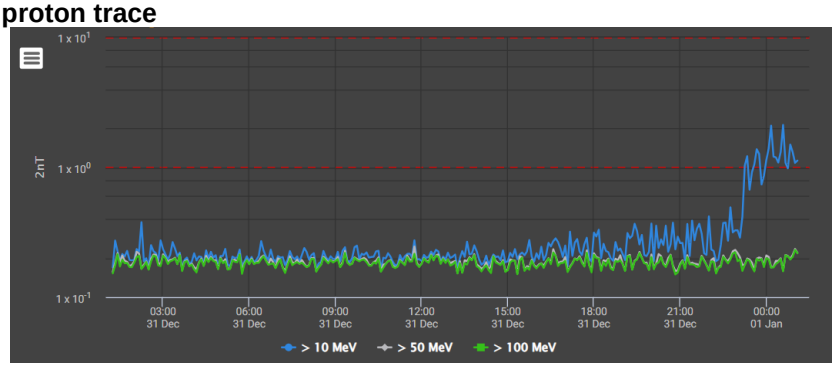
Solar Radiation Storms - (High Energy Protons):

GOES16 high energy (greater than 10MeV) proton flux is currently responding to the X5 flare from New Years Eve. Proton flux should remain below the S1 storm level, with a slight chance each day, initially due to the X5 flare and each subsequent day should any further notable flares occur.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

Figure 4: 24 hour proton trace



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

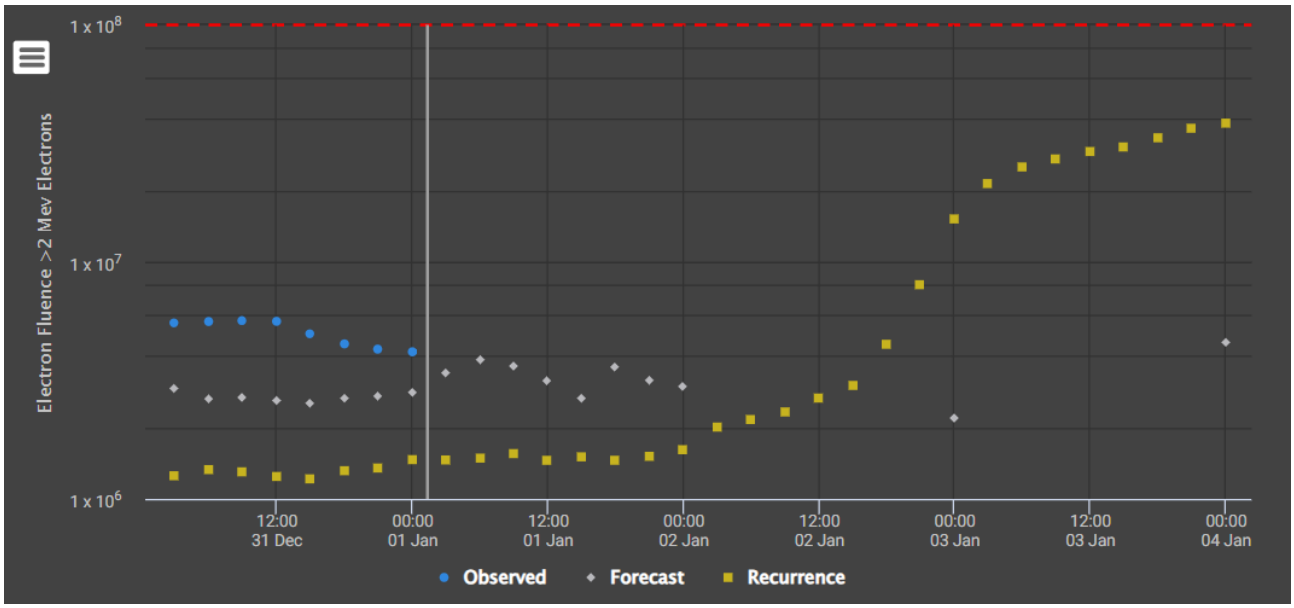
High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) has seen diurnal fluctuations between background and moderate. Flux is likely to drop out to mainly background with the onset of the fast wind of CH86, before increasing to Moderate from day 3 (03 Jan) with an increasing chance of peaking at High by day 4 (04 Jan).

Electron fluence is expected to remain well below the Active (1e8 integrated pfu) threshold, but likely with a gradually increasing trend from day 3 (02 Jan) as a result of the fast wind onset. This is in line with REFM which is currently giving good guidance.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	1	10	15
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 5: MOSWOC REFM



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.